14 Future Developments: Wood Protection for Aquatic Environments

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The effective prolongation of wood service life through preservative treatment has been a commercial reality for almost 175 years. Over that time, we have seen the development of some new treatment processes, but these have been primarily variations on the original full cell process. At the same time, treatment processes and post treatment procedures have been modified to reduce chemical consumption and decrease the potential for uncontrolled migration of chemicals into the surrounding environment.

Although public interest in environmental protection has been growing since the 1960s with the publication of Rachel Carson's *Silent Spring* (1962), the last two decades have witnessed ever-increasing regulatory pressure, and this pressure has affected the use of treated wood. The trend is unlikely to change and this will place added emphasis on the need to continue to improve processes, develop better information on migration rates of existing systems, develop safer chemicals, and explore new technologies for limiting migration.

While process changes have played an important role in maintaining the wood treating industry, changes in the wood preservatives themselves have had the greatest impact. The development of creosote ushered in the era of effective wood protection, but cyclic availability and the unsightly appearance and smell of the treated products encouraged development of both oil-based replacements such as penta and waterbornes such as CCA.

These systems dominated the industry for almost five decades and have only recently been displaced by changes in availability or label restrictions in the case of CCA. As we view the changes in wood protection that are currently underway, it is important to look forward to the next period of innovation. This is particularly important for wood protection because product development requires long initial testing to ensure adequate performance under adverse environmental conditions.

At the same time, it is important to recognize that wood is used in a regulated environment in the midst of a general public that is increasingly sensitive to the use of chemicals and to releases of chemical in the environment. Producers of treated wood must recognize that while they produce an almost carbon neutral product from a renewable resource, they must continue to reduce the impact of their products. Innovation will be key in these efforts.

Innovation can include new processes, new chemicals, non-biocidal protectents, the use of barriers and better tools for assessing the impacts of treated wood use.

14.1 Improving Process

The pressure-treating processes remain flexible, reflecting the fact that North American standards are results oriented, leaving most process decisions to the treater. There is no single process that will produce uniform treatment while minimizing preservative movement that works for all wood species or treatment chemicals.

At the same, there is a need for the development of processes that better immobilize chemicals in the wood. This is no simple task. Wood is differentially permeable and preservatives must be capable of moving through exceedingly small pores. Recent attempts to use supercritical carbon dioxide solvent represents one alternative treatment approach. This process overcomes some of the inherent issues with conventional oil or water-based systems, although it does not alter the water solubility of the active chemical. At present, new processes such as these are not cost competitive in most applications.

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14.2 New Chemicals

The most dramatic short-term developments in wood protection are likely to occur through replacement chemicals. The most notable change will be a shift away from heavy-metal-based wood protection and towards organic systems. While creosote was our first organic preservative, its broad toxicity and handling characteristics make it difficult to use in most consumer applications. The next generation systems are highly specific to various agents of decay and largely biodegradable. These attributes markedly reduce potential environmental impacts, but they also increase the risk of early failure, particularly in soil or marine exposures. The use of these systems may require a reconsideration of product service life. This will have obvious implications on life-cycle costs in comparison with competing materials. One of the major benefits of treating wood is extending service life, thereby reducing the need to harvest additional trees. New products should provide at least a service life that is long enough to allow a replacement tree to grow to harvest.

Although an obvious way to address issues related to currently used systems is to develop safer systems, this is a difficult process. While wood preserving is a reasonably large industry in North America, it is not large enough to support all of the costs associated with chemical development. As a result, most wood preservatives originate in the agricultural industry. In addition, proving the efficacy of a system requires long term testing under field exposure conditions. This process takes a minimum of 3 to 5 years, but can take even longer for critical applications such as utility poles, where failure of the product has life and safety consequences. Given the time required to develop a new system, any systems that emerge in the next 3 to 5 years are likely already under evaluation.

The recent shift to organic systems began with the introduction of alkaline copper quaternary systems in the early 1990s, followed by alkaline copper azole. Both of these systems contain substantial quantities of copper along with carbon-based biocides as secondary components that are added to protect against copper tolerant organisms. However, we have already seen that copper retentions required for the marine environment present significant challenges from an environmental viewpoint since so much more chemical is available to migrate from the wood.

Quaternary ammonium compounds and triazoles can be used as stand-alone biocides, but their use is largely limited to above ground or non-soil contact applications. This is because more recently developed organic biocides tend to be more specific than traditional heavy-duty totally carbon-based wood preservatives such as pentachlorophenol. The more specific modes of action reduce the risk to non-target organisms, but increase the likelihood that tolerant organisms will be capable of degrading the biocide. One solution to this problem is to employ mixtures of biocides with different modes of action to reduce the risk that tolerant organisms will overcome the protection. This approach is similar to the use of creosote, which consists of low levels of hundreds of compounds that act collectively to protect wood. Although the use of systems with hundreds of components would be prohibitively expensive, multi-component systems will be essential for making carbon-based biocides viable in extreme biodeterioration environments.

At present, applications for carbon-based systems using more recently developed biocides with specific modes of action remain limited to non-soil contact applications. As these systems are more thoroughly explored and understood, it is likely that they will be used in more aggressive environments. However, the diverse biological challenges present in marine environments make it rather less likely that complex carbon-based preservatives will provide a cost effective solution for protection of wood products in the marine environment.

The next generation organic systems do offer tremendous opportunities for reducing potential biocide inputs into the surrounding environment as many carbon-based systems have fairly low water solubilities, making them less likely to migrate from the wood. The addition of various resins and binders can help to further immobilize these compounds and these additives can be tailored to the system and the wood. It is important to remember, however, that biocides must be absorbed by the target organism to be effective. That means that they must be soluble in the water in the wood cells at levels that are at least toxic to the target organism. This means that formulation chemistry must achieve a balance between limiting solubility and allowing enough to solubilize to provide protection.

14.3 Alternative Approaches

A variety of alternative methods for protecting wood have been studied over the past four decades and many others are being re-examined in response to concerns about chemicals in the environment. Some of the technologies being actively examined include acetylation, thermal modification, and various "non-toxic" barrier treatments.

Acetylation was developed in the 1950s and involves reacting wood with acetic anhydride to complex the hydroxyl groups in the wood. This, in turn reduces the water holding capacity of the wood, making it less suitable for biological attack. Acetylation has been successfully used in Europe to treat various specialty items, but its primary drawback has been cost. Effective acetylation requires a very high loading or weight gain. In addition, the acetylated wood appears to be less resistant to termites and perhaps marine borer attack. However, it appears likely that some form of wood modification will provide one of the next generation of treatments for wood in the marine environment with regards to the necessary performance and environmental parameters. As a note of caution, such developments remain a distant promise in an era of very low research focus into protection of wood in the marine environment.

An area often seen as similar to wood modification is thermal treatment of wood. This technique uses non-oxidative heating of wood to modify the availability of the carbohydrates, thereby reducing the risk of decay. However, thermal processes do not reduce the risk of termite attack on wood, and it is unlikely that they will control marine borer attack. Currently, thermal treatments are used primarily for applications where wood is exposed above ground such as in cladding for houses. A further challenge for thermal treatments is that they can have a significant impact on wood strength properties, which is problematic in applications such as piling.

One area of research that has received little attention is improving natural durability through either developing improved silvicultural methods or genetic modification of trees to provide materials with enhanced natural durability. It has been known for many years that certain wood species such as *Syncarpia glomulifera* (Turpentine) have very high natural durability in the marine environment because of their high natural silica content in the wood. These trees, however, are often found in old growth forests that are protected for a host of societal reasons. Many countries have developed plantations of these same species with the goal of sustainably producing durable woods. Unfortunately, the durability of these fast-grown plantations woods is often lower than the original trees. For example, plantation grown *Syncarpia glomulifera* with low silica content has much reduced durability against marine organisms. Clearly, there may be opportunities to develop plantation grown hardwoods that provide the necessary natural durability as seen in old growth *Syncarpia*. This tree improvement will most likely occur through traditional breeding strategies although it could also occur more recently development genetic techniques. It may also come through developing a better understanding of how silviculture may be used to produce trees with more durable heartwoods. Supplies of durable plantation species are unlikely to ever completely meet our needs for biologically resistant materials, but they could help meet needs for specific, highly sensitive environments.

14.4 Barriers to Reduce Migration

The other emerging trend with treated wood used in sensitive environments has been the use of supplemental coatings. Regulators in a number of situations have recommended that treated wood exposed over water be protected or otherwise coated to retard chemical migration. While coatings can retard migration, they are relatively temporary and must eventually be reapplied. Failing paint films often act as water traps and can lead to higher moisture contents that enhance decay in larger timbers. In addition, reapplication can be costly and difficult in complex structures, particularly over water.

Alternatives to paints or other coatings include fiberglass wraps and polyurethane coatings. Fiberglass wraps have long been used to reinforce weakened wood in service, but they are costly. Urethane coatings are similar to those used for truck bedliners. They can be applied in various thicknesses depending on the applicator. The Port of Los Angeles performed an extensive international trial of polyurethane coated wood that showed excellent performance. These coatings do not completely seal the wood, but they could sharply reduce potential chemical movement.

While the overwhelming volume of data has shown that properly treated and installed preservative treated wood has no negative effects on non-target organisms in the vast majority of applications, there are situations where barriers might be useful. These include extremely poorly flushed aquatic areas or areas where large amounts of treated wood have or will be used. Barriers may eventually allow the use of less biocide in the wood. Barriers separate the wood from soil or the marine environment, sharply reducing the degree of biological hazard. This could permit the use of lower chemical retentions. Suggestions have been made to use coated, untreated wood, but this provides little protection in the event that the barrier is compromised. Recent tests of coated Douglas-fir lumber showed that Formosan termites rapidly detected and destroyed untreated wood despite a polyurea coating, but did not damage similarly coated penta treated wood. There is a need for further testing to evaluate the ability of coatings to protect wood treated to lower retentions, as well as the ability of the barrier to retard chemical migration from the wood.

14.5 Best Management Practices

Treated wood use has markedly extended the service life of a host of products, thereby reducing the need to harvest trees. The near carbon neutrality of these materials makes them even more attractive. However, the potential for preservative migration off sets these advantages and merits much further work to better understand the risks associated with preservative use, develop methods for reducing migration and develop new systems with lower environmental impact.

The Best Management Practices Systems are one component of that process, but they are far from perfect. There is a critical need to keep improving BMPs. It will also be important to develop reliable methods for confirming BMP compliance. At present, BMPs are primarily used in the western United States, but interest in their application continues to grow. In general, BMPs are process-oriented, for example, directing the treater to use combinations of initial and post treatment vacuums to reduce over treatment and bleeding. They can also include heating to relieve pressure, steaming to clean the wood surfaces, filtering treatment chemicals to reduce the risk of sludging and a host of other activities designed to reduce the potential impact of treated wood. Most of these activities are not quantifiable. There is a critical need for the development of tests to assess BMP quality on all of the so-called heavy duty wood preservatives as well as a need for verifying that these processes actually result in a reduced environmental impact.

14.6 Conclusion

The move from the petroleum age to what we hope is an increasing dependence on renewable materials should allow wood products to play an important role. The continued contribution of durable wood to this shift will depend on the ability of researchers to improve treatment processes to minimize chemical loss, to develop less broadly toxic biocides, to embrace alternative treatments where they are practical, and continually seeking new ideas that can further reduce the environmental footprint of wood.